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NBS-AF Panoramic X-ray Machine Speeds Examination and Reduces Radiation

AN X-RAY MACHINE that rapidly takes a single panoramic X-ray picture of the entire dental arch has been developed by the National Bureau of Standards in cooperation with the U. S. Air Force Dental Service and the USAF School of Aviation Medicine. The panoramic X-ray machine should be particularly useful to the armed forces in making full-mouth dental X-ray surveys of inductees on entering and leaving the service. It will save much of the time required by present techniques, in which up to 14 small films are exposed separately for a full-mouth survey. The device should find application wherever large numbers of people are examined for dental defects, and its principles can be applied to radiography of other parts of the body.

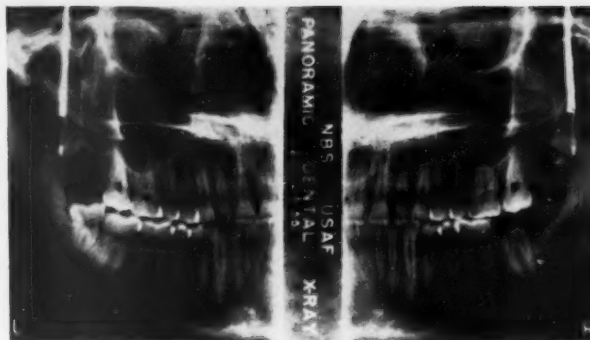
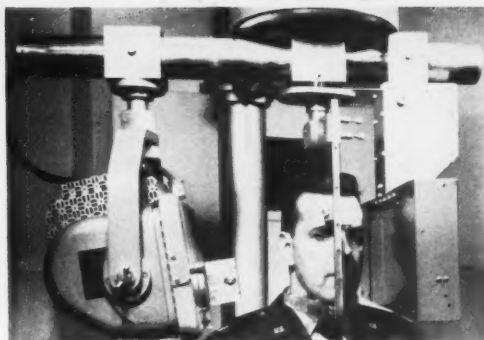
In the NBS-AF panoramic machine, the film is placed outside the patient's mouth and is exposed by passing a narrow beam of X-rays through his head. A panoramic X-ray picture of all the teeth and associated structures is obtained on a single 5×10-inch film in about 40 seconds. Thus the problem of handling small film packets during exposure and processing is eliminated. At the same time more comprehensive radiographs are produced, giving more general diagnostic information than do conventional full-mouth X-ray surveys.

For several years investigators in both the United States,^{1, 2} and Finland³ have been seeking to develop a rapid, practicable method for making panoramic

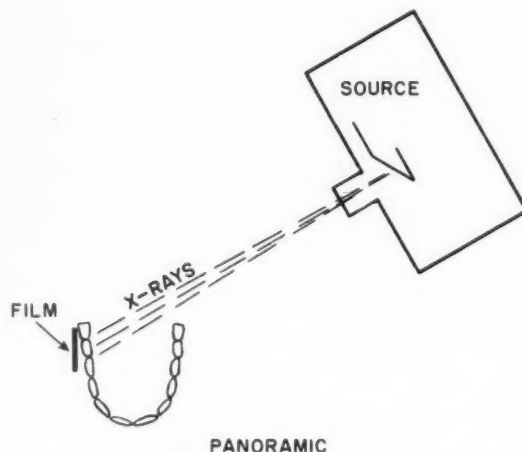
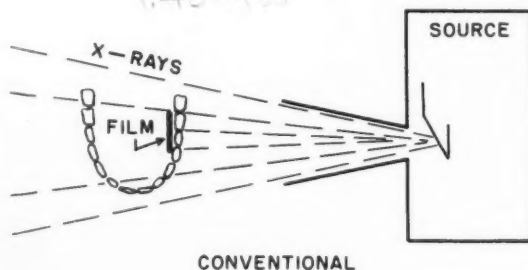
X-rays of the entire dental arch. However, the procedures that have been tried have been rather cumbersome—they required rotation of the patient or fitting films inside the mouth. Because of the large number of full-mouth surveys that must be made of military personnel, particularly at induction stations, a rapid, dependable method was needed to replace conventional radiographic techniques. Funds for research in this field were therefore provided by the Air Force. As a result, a more flexible and simple panoramic machine was developed by Col. D. C. Hudson, NBS guest worker from the U. S. Air Force Dental Service, and J. W. Kumpula of the Bureau staff, with the cooperation of members of the NBS electronic instrumentation laboratory.

In this machine, an X-ray source and film holding device follow semicircular paths on opposite sides of the patient's head. The film holder travels in front of the patient, the X-ray source behind him. Movement of source and film is so coordinated that only those structures of the dental arch desired in the finished film are sharply projected while other overlying structures are not.

The X-ray source and film holder are suspended from opposite ends of a horizontal arm that rotates about a central vertical axis. A narrow beam of X-rays emerges from a slit in the exit cone of the X-ray source, passes through the subject's head, and enters a corresponding slit in the film holder just



NBS-AF panoramic X-ray machine in operation and typical X-ray picture results. Developed by NBS in cooperation with the Air Force, this device rapidly takes a single X-ray picture of entire dental arch. X-ray source (left) and film holder (right) travel in semicircular paths on opposite sides of patient's head. X-ray beam enters patient's head from rear, passes through his head, and enters a slit in the film holder just beyond his teeth. Above patient's head is a cam curved in the shape of average dental arch. As the cam rotates, a cable wound about the cam moves the film within holder; as a result, the film travels at a rate which conforms to size and shape of dental arch. The radiograph was made on a phantom head. Parts of nasal sinuses and other bony structures of head can also be observed. Strip in center normally carries patient's name and date.



Model of human head (left) used to study radiation levels produced by NBS-AF panoramic X-ray machine. Head was constructed of tissue-equivalent wax molded upon a human skull. Ionization chamber in cheek is used to measure X-radiation at that point. Cavity is used for measurements in neck region. Diagrams show how machine reduces amount of radiation which patient receives during a dental X-ray survey. In conventional technique as many as 14 small films are exposed separately inside the patient's mouth. Each exposure requires a broad beam of X-rays that necessarily increases area of patient's head exposed to radiation. In panoramic machine only one narrow X-ray beam is used.

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beyond his teeth. Meanwhile, the film, in a carrier within the holder, travels horizontally in a direction opposite to that of the holder and at such a rate that an X-ray shadow of each successive tooth falls on successive areas of the film.

To avoid unwanted X-ray shadows from overlying bony structures, the X-ray beam is made to enter the patient's head largely through the soft tissue between the vertebral column and the bone of the jaw—first from one side, then from the other. As the system rotates, the axis of rotation of the X-ray beam is in this soft tissue, which is much more transparent to X-rays than are the harder structures. Thus, since the X-ray beam is in constant motion, shadows cast by intervening bone and other tissue, between the point of entry and the dental arch, move across the film too rapidly to obscure detail in the exposure. As a result, clearer lateral jaw radiographs can be obtained than with conventional techniques.

A simple mechanical system automatically varies the rate of film travel to conform to the size and shape of the human dental arch. This device consists of a cable wound about a cam which is curved in the shape of an average dental arch. The free ends of the cable are connected through pulleys to the film carrier. As the horizontal arm rotates at constant speed, the film moves at a rate determined by the curvature of the cam surface at the point where the cable is leaving the cam. The cam is fixed at the axis of rotation. An electric motor rotates the arm supporting the X-ray source and film holder. A central panel controls the motor as well as X-ray voltage and current.

The first model of the panoramic X-ray machine is now undergoing performance studies. In this model the patient sits in a dental chair beneath the rotating arm and is positioned by means of a chin support pivoted from a stationary point on the machine. The chin support serves to steady the head and to place the dental structures in the proper position for best projection onto the moving film. Future models may be so constructed that the subject need not sit but may be radiographed in a standing position. This will further reduce the time needed for a dental survey.

With the cooperation of the Naval Medical Research Institute, a study⁴ was made of the radiation levels produced by the panoramic X-ray machine at points in and about a phantom head constructed of tissue-equivalent wax molded upon an adult human skull. By the use of small ionization chambers—about 30 mm³ in volume—it was found that the panoramic device produces lower radiation levels than the conventional 14-film intraoral technique produces at corresponding points. The reduction in radiation received by the patient is due to the small area covered by the beam of X-rays during panoramic exposure and the fact that no overlapping occurs.

¹ U. S. Patent 2,476,776, issued to H. Smathers.

² Panorgraphic radiography, by R. J. Nelsen and J. W. Kumpula, *J. Dental Research* **31**, 158 (April 1952).

³ Pantomography in theory and use, by Y. V. Paatero, *Acta Radiol.* **41**, 321 (1954).

⁴ Ionization chambers for radiation data during dental X-ray exposure, by D. C. Hudson and J. W. Kumpula, *Armed Forces Medical Journal* **6**, 1131 (August 1955).

Fire Hazard of Nitrocellulose Motion Picture Film

THE BUREAU'S fire protection laboratories have completed an extensive study of growth of fires and means for their control in storage vaults for combustible nitrocellulose motion picture films. Test results indicate that through the proper use of sprinklers and film storage racks, it may be possible to limit film loss to the single roll where the fire starts. In this study, the amount of film stored, vent area of the storage vault, sprinkler systems, film cans, types of storage racks, and other variables were investigated for their effects on the amount of film destroyed by fire and on the gas pressure developed in the vault. Results show the relative effectiveness of various safety devices in minimizing fire loss and danger to surrounding property. The study was undertaken for the National Archives and for the Inter-Agency Advisory Committee for Nitrate Film Vault Tests, an organization made up of representatives from both Government and private industry.

A number of severe fires and explosions occurring in nitrocellulose film storage and distribution facilities led the U. S. Geological Survey in 1910 to make some small scale tests to determine the pressures developed by burning film in a vented chamber as a function of film load and vent area. The National Fire Protection

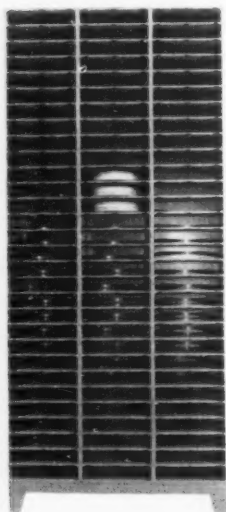
Association published the results of a series of similar tests made on a larger scale in 1915. The results of each of these investigations led to the conclusion that the maximum allowable loading of film in a vault should be about 7 pounds of film per square inch of vent area. However, NFPA recommended less dense loading and advised placing the film rolls in close-fitting metal cans. Later experience with actual fires disclosed that gas pressures higher than those determined experimentally were generated in some storage facilities. To uncover further information about such fires and to determine safe practice for storing films, the Bureau undertook a large scale experimental study of nitrocellulose film fires.

The study covered the effects of film cans, open and compartmented film storage racks, the use of insulation in the racks, film load, type and size of vent, types of sprinkler heads and systems, and the water flow rate through the sprinklers. Observations were made of the pressures and temperature distribution in the storage vault, fumes and flames issuing from the vault, extent of film damage, and the operation of sprinklers with their associated detectors. Three film chambers were employed: A steel chamber of 22 ft³ volume, a



A fire test of a large nitrocellulose film vault resulted in this violent discharge of flames, film cans, and film over distances up to 300 ft. Such tests indicate that using only vertical discharge vents and isolating film vault buildings are advisable. (Photo courtesy of National Archives.)

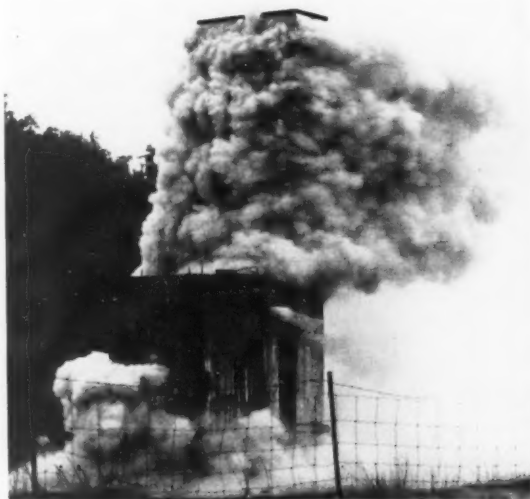
reinforced concrete chamber of 128 ft³, and a reinforced concrete vault of 373 ft³ volume. The last was in the form of a room 8 ft deep, 4 ft 8 in. wide, and 10 ft high and was one-half the maximum volume recommended in widely recognized standards for film vaults. Each chamber was equipped with temperature and pressure measuring instruments. The first, designed for the investigation of the load-to-vent relationship and the effectiveness of film cans, had only interchangeable vents as additional equipment; the second, designed to permit greater total loads, had only interchangeable vents and skeleton racks as additional equipment; and the largest, designed for the comprehensive study, was equipped with a door, a vertical discharge stack vent, a horizontal discharge window vent, various racks, detectors, and two sprinkler systems. In the largest chamber, each vent could be closed completely or adjusted to give the desired open area. Only one vent was opened for each test.



Maximum fire protection was afforded using a sprinkler system and storing film in racks similar to these but with metal doors covering the front of each compartment.

Film storage racks were the skeleton, open, open-front compartmented, and closed-front compartmented types. Each compartment in the rack was insulated and held a single 1,000-ft roll of 35-mm film in a film can. Fusible link sprinkler heads were used in standard and directed-spray systems and open or deluge sprinkler heads were used in a directed-spray system. The directed-spray systems were set with the centerline of the discharge striking the film racks at two-thirds of their height. In each test, a single roll of film was ignited by electric current through a nichrome heater wire wrapped around a match.

The results of preliminary tests in the steel chamber with film rolls not in cans agreed with those from the NFPA investigation. The results also showed that the relationship of pressure developed in a vented chamber



In this experiment, use of sprinklers inside the vault controlled flames from film on open storage racks, although all film was destroyed.

was a function of the ratio of film load to the vent area. Data from these tests show that film load-to-vent ratios above 5 lb/in.² will produce dangerous pressures. Therefore, most of the tests in the large vault were made with load-to-vent ratios of 5 lb/in.² Significantly lower pressures developed in the tests in the large vault where the film rolls were placed in cans. However, unless sprinklers were used and the cans placed in racks, all the film was burned out. With film cans in open or skeleton racks and protected by sprinklers, the amount of film destroyed ranged from 10 to 93 percent. The addition of insulation that approximated compartmentation of the skeleton racks, along with sprinkler protection, resulted in film loss as low as 2 percent.

The lowest film loss was obtained with the combination of sprinklers and closed-front compartmented insulated racks. In two tests, only the ignited roll of film was burned out, and 1 or 2 rolls in adjoining compartments were slightly damaged by heat. The re-

corded gas pressures were insignificant. In two other tests without sprinklers but with the same racks, only 5 rolls in one test and 8 rolls in the other test, including the ignited rolls, were burned out and the recorded pressures did not exceed 0.25 lb/in.² gage.

Aside from film loss considerations, the observed temperature data indicated that only masonry or other equally noncombustible construction should be used for film vaults. Horizontal discharge of flames and burning film over distances up to 300 ft from the vault clearly indicated the advisability of using only vertical discharge vents and of keeping film vault buildings isolated from other valuable property.

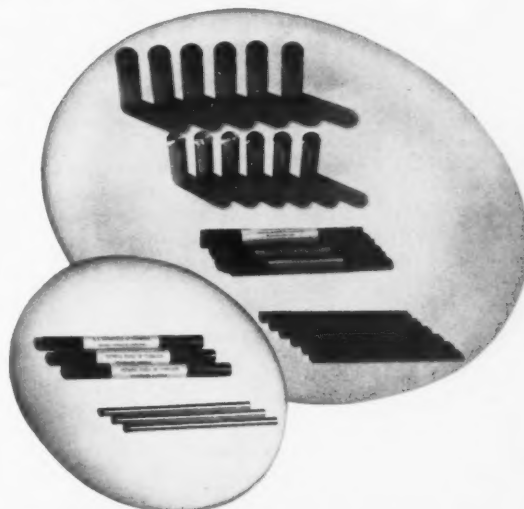
For further technical details, see Fire effects and fire control in nitrocellulose photographic film storage, by J. V. Ryan, J. W. Cummings, A. C. Hutton, BMS 145 (in press); for an earlier article, see Spontaneous ignition of decomposing nitrate film, NBS Tech. News Bull. 35, 153 (October 1951).

Spectrographic Standard Samples of Stainless Steel

THE BUREAU now has available six new standard samples of stainless steel. The samples, carefully analyzed and certified for composition, are designed for calibrating and checking spectrochemical methods of analysis. Together with a set of three spectrographic standards issued earlier, NBS standard samples now provide certified concentration values for determining most of the elements encountered in the analysis of stainless steels.

The new stainless steel standards are certified for concentrations of six major and minor elements: Manganese, silicon, copper, nickel, chromium, and molybdenum. Samples are available in two forms: Rods $\frac{7}{32}$ inch in diameter and 4 inches long, and rods $\frac{1}{2}$ inch in diameter and 2 inches long. Both forms serve as electrodes for spark excitation in spectrochemical analysis. The three stainless steel standards issued previously are certified for nine trace elements: Aluminum, boron, copper, molybdenum, niobium, lead, vanadium, tungsten, and zinc. These are available in the form of rods $\frac{7}{32}$ inch in diameter and 4 inches long.

Since spectrochemical methods of analysis are both fast and accurate, such methods have been increasingly applied to the analysis of complex steel alloys. Anticipating the growing need of industry for suitable standards, the Bureau began preparing the stainless steel samples several years ago. Six heats of metal were contributed by the Uddeholm Co. of Sweden, which prepared the steels to desired composition and fabricated the metal into rods. A grant from the American Iron and Steel Institute assisted the Bureau in homogeneity testing and analysis. Chemical analyses were made by four cooperating laboratories: Allegheny-Ludlum Steel Corp., Armco Steel Corp., Wilber B. Driver Co., and NBS.



Spectrographic standard samples of stainless steel are available from NBS as rods $\frac{7}{32}$ in. in diameter and 4 in. long, and $\frac{1}{2}$ in. in diameter and 2 in. long. They are certified for concentrations of six major and minor elements. Standard samples issued earlier (small circle) are available in $\frac{7}{32}$ by 4 in. size and are certified for nine trace elements.

The rods have a uniform grain structure resulting from hot-rolling and annealing the cast metal. The surfaces of the rods were finished by centerless grinding. The homogeneity of the rods, both in cross and longitudinal sections, was studied by spectrochemical analysis and was found satisfactory with respect to the concentrations of the certified elements.

The standards can be applied directly to the analysis

of stainless steel rods prepared in a similar manner and with similar dimensions. However, when the standards are applied to the analysis of steel samples prepared by other procedures, adjustments may be required to correct for variations introduced by physical differences.

The stainless steel standards may be obtained from the National Bureau of Standards for a fee of \$8.00 each. A provisional certificate supplied with the standards gives average values of the analyses reported by the cooperating laboratories. The compositions and sizes of the standards are given in table 1. In addition to the elements now certified, the standards also contain aluminum, niobium, tin, titanium, vana-

dium, and tungsten, some of which may be certified at a later date.

TABLE 1. Composition of NBS spectrographic standard samples of stainless steel

Sample numbers *		Mn	Si	Cu	Ni	Cr	Mo
		C _p	C _p	C _p	C _p	C _p	C _p
445	845	0.77	0.53	0.065	0.28	13.30	0.92
446	846	.53	1.20	.19	9.10	18.37	.43
447	847	.23	0.37	.19	13.26	23.73	.059
448	848	2.10	1.25	.16	0.52	9.10	.33
449	849	1.62	0.68	.21	6.62	5.48	.15
450	850	-----	.12	.36	24.8	2.99	-----

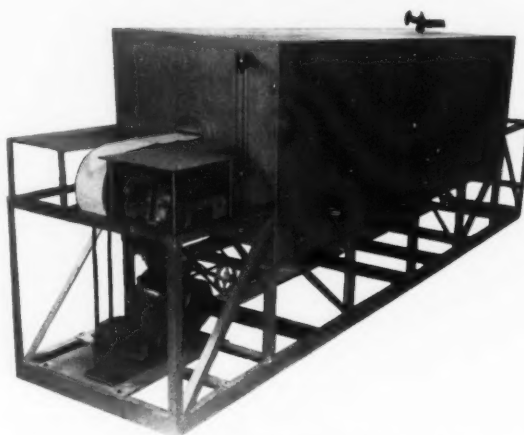
* Sizes: 400 series, rods 7/8 inch in diameter, 4 inches long.
800 series, rods 1/2 inch in diameter, 2 inches long.

Continuous Furnace for Curing NBS Tape Resistors

A CONTINUOUS FURNACE for curing tape resistors has been designed and constructed under the direction of B. L. Davis of NBS. The furnace uses a liquid heat exchange medium to achieve highly stable temperature control. The curing temperature can be held to ± 1 deg C on long-term operations. While built as a laboratory unit, the furnace is well suited for a production line facility. It processes each resistor identically and makes possible the manufacture of closer-tolerance tape resistors for module wafers or printed circuit plates. The furnace was designed primarily to meet the needs of the Mechanized Production of Electronics Program (MPE)¹ sponsored by the Navy Bureau of Aeronautics. It should be equally valuable for firing or annealing other materials where time and temperature must be accurately controlled and where a repeatable cycle of temperature rise and fall on entering and leaving the furnace is important.

The NBS self-adhesive tape resistor consists of a carbon formulation applied to an asbestos-paper tape base. Composition of the formulation and the variety of the carbon determine the resistance value since the resistors are cut to the same size—0.130 by 0.300 in. After the resistor has been placed in a printed circuit, it must be cured to fix its resistance value. As many as four resistors, mounted on a ceramic plate bearing a fired silver conductor pattern, are cured by placing in an oven and heating to a predetermined temperature for a prescribed period of time. Because of the different carbon formulations, each resistor may require different temperature and time curing schedules. Since it is clearly impossible to cure the resistors in the assembled circuit according to individual schedules, a compromise was adopted for curing all resistors. This compromise schedule, based on results obtained from experiments performed on over 6,000 tape resistor specimens, was a governing factor in the design of this continuous furnace.

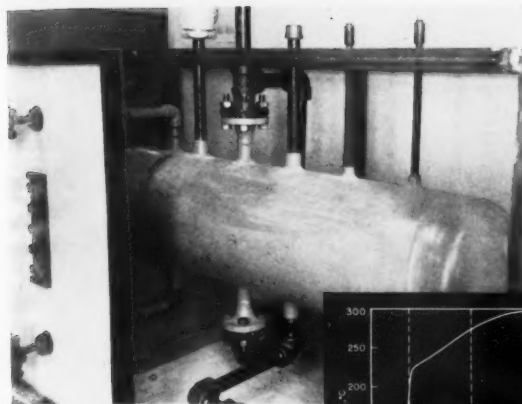
In the new NBS furnace, the resistors move on a continuous belt through a pair of concentric Schedule 40 steel pipes 9 1/2 ft long. The inner pipe is 6 in. in



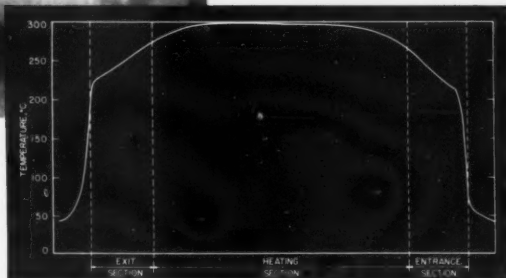
Continuous furnace designed at NBS for curing tape resistors. It uses a liquid heat exchange medium to achieve highly stable temperature control. Furnace processes each resistor identically and makes possible manufacture of closer-tolerance tape resistors.

diameter while the outer pipe is 8 in. in diameter. The space between the two pipes is sealed at both ends and at two intermediate positions, thus providing three independent chambers. The two end chambers are each 1 1/2 ft long, and the intermediate, or heating, section is about 6 1/2 ft long. An organic heat transfer medium—a eutectic mixture of 26.5 percent diphenyl and 73.5 percent diphenyl oxide²—passes as a vapor into the intermediate section. Here it gives up some of its heat, condenses, and returns to the vaporizer. With a condensing vapor, all the heat is transferred at the saturation temperature, thereby maintaining all the heated surface at the same temperature. The condensate returns by gravity, thus providing circulation without pumps.

The two end chambers are filled with the liquid heat exchange medium. The thermal inertia and the convection currents within the liquid help stabilize the



Vaporizer shown above is used with NBS continuous furnace. Organic heat transfer medium passes as a vapor into furnace, gives up its heat, condenses, and returns to vaporizer.



Temperature distribution curve shows that temperature, in the center section, can be held to ± 1 deg C on long term operations.

temperature gradients of the end sections. In addition, a heavy copper liner inside the inner pipe helps insure stability in the temperature gradients, from the room temperature at the outer ends of the furnace to the curing temperature that is maintained throughout the intermediate chamber. The center section can be held to within ± 1 deg C of its normal operating temperature.

A continuous belt carrying the resistors moves axially through the inner pipe. Belt speed and curing temperatures are adjustable over a wide range. Normally, however, the NBS tape resistors, when mounted on printed circuit plates, are cured at 300°C and spend 4 hours in transit from cold entrance to cold exit. One hundred seventy-five resistor wafers used in the NBS-MDE (Modular Design of Electronics)¹ module can be accommodated each hour.

The unusually stable curing temperature of the furnace is maintained by controlling the pressure of the heat transfer medium in its vapor state. Diphenyl-

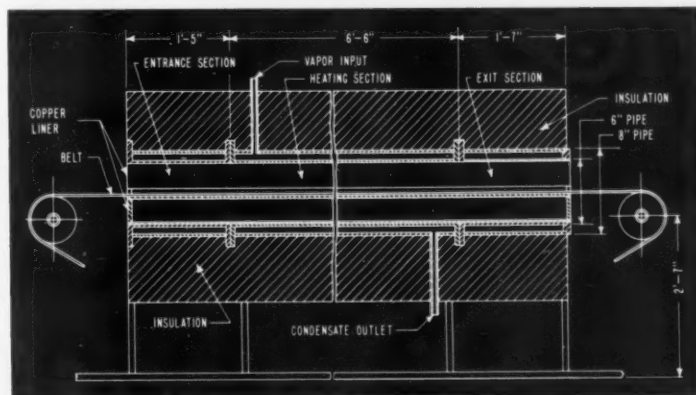
diphenyl oxide was chosen for this application because of its low pressure-to-temperature ratio—20 psi at 300°C . In the region of this temperature, a pressure change of 3.6 psi produces a temperature change of 5.5 deg C. Such a pressure change is easily detectable with conventional equipment. The pressure-control system maintains the maximum furnace temperature by regulating, on an on-off basis, the electric heater power of the vaporizer.

The furnace was designed for safety and dependability. The vaporizer and furnace were tested at over

100 psi before being put into use. The control circuit is designed for fail-safe operation. Temperature indicators and over-temperature cutoff instruments monitor both the vaporizer and the furnace, and a safety valve is provided for the vaporizer. Manual control stations are used in an emergency to cut off the power to the vaporizer and to stop the belt drive.

¹For additional information on the Bureau's Modular Design of Electronics—Mechanized Production of Electronics program, see Project Tinkertoy, NBS Tech. News Bull. 37, 161 (November 1953); Recent advances in electronic process technology, NBS Tech. News Bull. 39, 1 (January 1955) also available from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., Vol. I—Summary MDE and MPE, PB111275 (\$2.00); Vol. II—Conversion from Conventional Design to MDE, PB111276 (\$2.00); Vol. III—Hand Fabrication Techniques, PB111277 (\$2.00); Vol. IV—Mechanized Production of Electronics (MPE), PB111278 (\$4.00); Vol. V—Manufacturing Cost Determination, PB111315 (\$4.00).

²"Dowtherm A," available from Dow Chemical Co.



Cross-section drawing of the NBS continuous furnace.

FORWARD SCATTER—a recently discovered mode of radio propagation—promises to extend greatly the limits of long-distance communication. Through application of scatter propagation, new frequency channels can be opened up to long-range use, new path lengths can be utilized, and reliable service can be provided far beyond the line-of-sight limit in the extreme high-frequency ranges. Both industry and the armed services anticipate savings through elimination of many relay stations.

In view of the current general interest in scatter propagation and the importance of the subject to radio communication, the Technical News Bulletin is presenting a comprehensive report on NBS activities in this field. Part I of the report, beginning on this page, is concerned principally with studies of ionospheric forward scatter. Part II, dealing with tropospheric scatter experiments and the theory of forward scatter, will appear in the February issue.

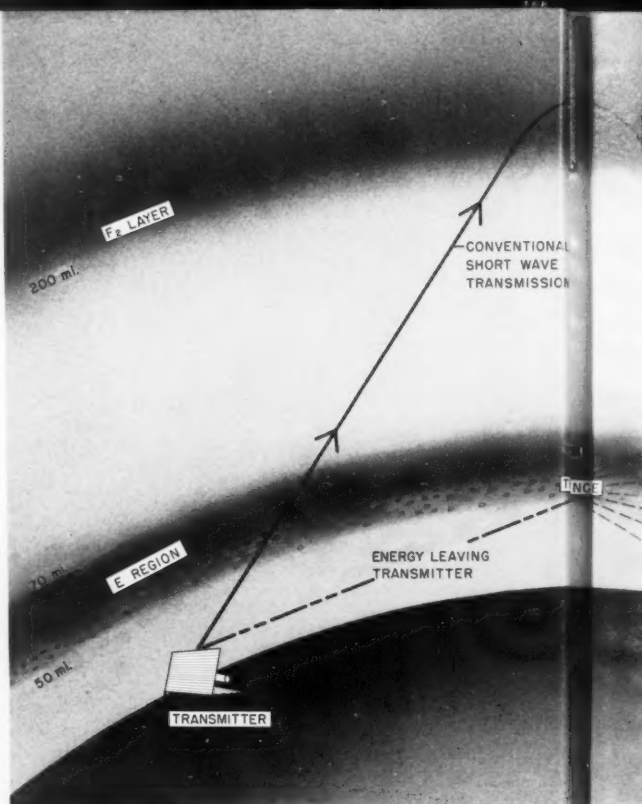
Radio propagation by forward scatter is believed to result from small inhomogeneities due to turbulence in the atmosphere. These inhomogeneities scatter radio waves in all directions, but predominantly forward. With properly designed equipment, the scattered signal can be received over long distances along the earth's surface even though the direct wave has gone off into outer space.

While this phenomenon has been known to science for several years, extensive research has been necessary before it could be successfully applied to radio communication. For more than 5 years, forward scatter has been the subject of intensive experimental and theoretical investigation at the National Bureau of Standards. Sponsored by the Department of Defense, this work has not only provided insight into the nature and causes of the scattering process but has also laid much of the groundwork for effective application of forward scatter in practical communication circuits.

The NBS program has included both ionospheric and tropospheric forward scatter. Ionospheric scattering takes place in the lower part of the ionosphere—a region of electrified particles 40 to 200 miles above the surface of the earth. Tropospheric scattering occurs in the part of the atmosphere that lies below the ionosphere.

Tropospheric forward scatter appears to be useful for transmissions over distances up to 600 miles, such as in air-to-ground communication between a plane in flight and its control tower, at frequencies from 100 to at least 10,000 megacycles per second. Ionospheric forward scatter permits communication in the frequency range from 25 to approximately 60 Mc. and over distances extending from approximately 600 to 1,200 miles.

Beginning with frequencies where radio waves are no longer reflected by the ionosphere as they are in ordinary long-distance transmissions, ionospheric forward



Forward Scatter of Radio Waves A New Means of Communication

scatter extends into the very-high-frequency (VHF) region,¹ a part of the radio-frequency spectrum formerly considered useless for long-distance communication on a regular basis. In the regions where transmission is by tropospheric scatter, the available frequencies are increased many fold. Scatter propagation also helps to fill in gaps of path lengths that have not been satisfactorily covered.

NBS research in both areas has progressed simultaneously. The tropospheric program has been centered at Boulder, Colo., with the principal transmitters on Cheyenne Mountain near Colorado Springs and receiving stations in eastern Colorado and Kansas. The ionospheric work has utilized a variety of paths to evaluate variables such as the effects of the auroral zone. One of these paths—between Cedar Rapids, Iowa, and Sterling, Va.—has been used continuously for nearly 5 years.

Part I. Ionospheric Forward Scatter

When radio waves were first discovered, they were shown by physicists to be transverse electromagnetic waves identical to those of light except for their frequency of vibration. It was therefore believed that they would no more go beyond the visible horizon than

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WAVE
MISSION

ANCE

TRANSMITTED
ENERGY (LOST)

SCATTERED
ENERGY

RECEIVER

nt of Radio Waves ean Communication

would light rays bend around a corner. However, in thus simplifying the problem, the physicists of that time apparently overlooked the fact that light rays are reflected from mirrors and that they are scattered by atmospheric irregularities such as clouds or fog. When Marconi demonstrated in 1901 that radio waves could be received across the Atlantic Ocean, there was at first no satisfactory explanation for his observations. Search for such an explanation eventually led Heaviside and Kennelly to propose that high up in the atmosphere there are layers of electrified particles, or ions, capable of reflecting radio waves much as a mirror reflects light waves. Thus radio waves can be propagated far beyond the visible horizon by reflection from these ionized layers, known collectively as the ionosphere. Ionospheric reflection has been for years the basis of all radio circuits more than a few hundred miles in length.

Scattering of radio energy by the ionosphere is similar to the scattering of light by small water droplets in a cloud or fog. When a beam of light shines through the mist, moving points of light are seen in the beam. These are water droplets, ordinarily too small to be seen, scattering light out of the beam toward the observer. Similarly, irregular variations in the structure of the ionosphere are believed to result in the scattering of radio waves.

In conventional shortwave transmission, radio waves are transmitted beyond the visible horizon by reflection from the outer layers of the ionosphere, usually in the *F* region. In ionospheric scatter propagation, energy scattered by turbulence in the lower part (*E* region) of the ionosphere provides the received signal.

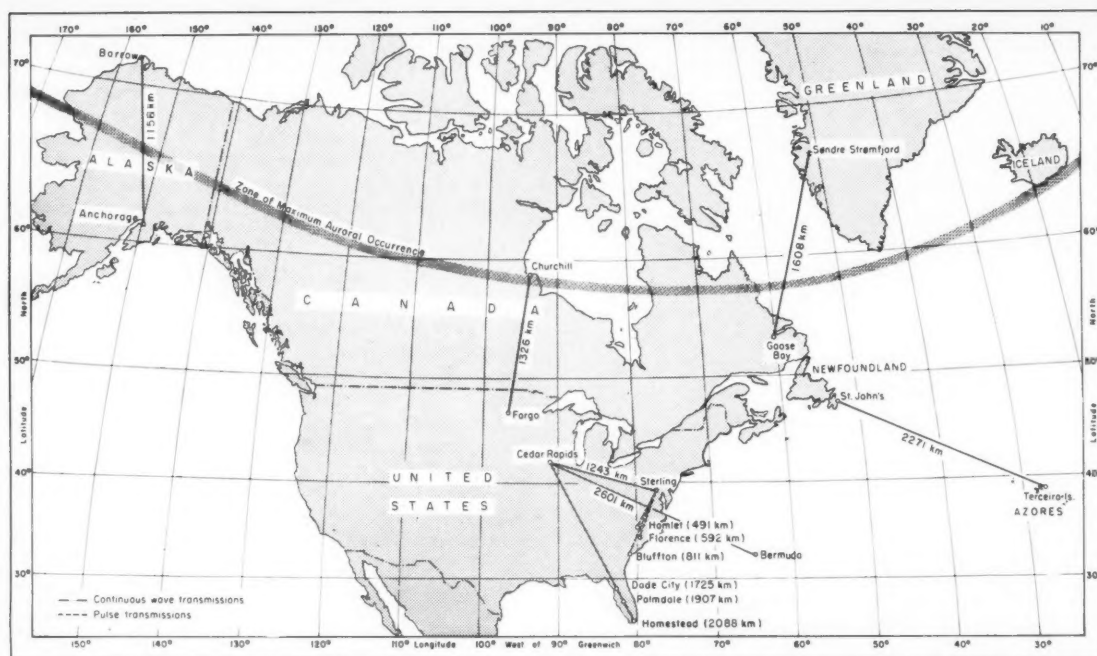
Ionospheric forward scatter is characterized by its high reliability under practically all conditions. During auroral disturbances, which cause polar blackouts of ordinary high-frequency ionospheric communication, scattered signals usually become stronger. Also, strengthening is often observed during sudden ionospheric disturbances, which are associated with solar flares and cause short-term blackouts of high-frequency communication throughout the daylight hemisphere.

Auroral storms and polar blackouts constitute one of the most serious problems in arctic communications. Hitherto attempts have been made to obtain reliability during such disturbances by changing frequency of operation. This, of course, requires installation of multiple transmitters, antennas, and receivers. A single ionospheric scatter circuit, while expensive in itself, can provide more reliable service at a single frequency and less cost.

It is generally agreed that scattering takes place from that part of the lower ionosphere known as the *E* region. Ionospheric layers exist in this region at various heights, usually between 80 and 110 km above the earth's surface. Ordinarily, radio waves (i. e., up to about 25 Mc) pass directly through the *E* layers and are reflected from outer layers, usually in the *F* region. However, there is some quality about the *E* region which causes VHF radio waves to be scattered in all directions when they strike it. This scattering can occur from a large number of small irregularities in the ionization of the atmosphere, much as light is scattered from the large number of small water droplets in a cloud or fog. A very small portion of the scattered energy will reach a receiver which is pointed directly toward the spot where the incident wave strikes. This principle may be utilized for radio communication if (1) the radio wave is transmitted with sufficient power, (2) the transmitting antenna has high gain and is properly directional, and (3) a high-gain directional receiving antenna is used.

At least three major factors contribute to the ionization of the *E* region, which causes ionospheric scatter: Direct solar radiation, corpuscular radiation, and meteors. The contributions of each mechanism are not known exactly and need more study. Some observations, however, seem to identify behavior noted at different times with specific mechanisms.

In a series of measurements over an arctic path (Anchorage to Barrow, Alaska) correlation with magnetic activity indicated a rise in signal strength at the receiver with increasing magnetic activity at the midpoint (Fairbanks). One explanation is that the contribution of the corpuscular radiation factor at these times is high. Corpuscular radiation, presumably of solar origin, consists of atomic particles of matter. These particles take from 18 to 30 hours to reach the earth from the sun. When they enter the earth's magnetic field, they are caught up by it and spiral toward



A variety of experimental paths have been used in NBS studies of ionospheric forward scatter. The original path between Cedar Rapids, Iowa, and Sterling, Virginia, has been operating continuously since January 23, 1951. Three paths crossing or terminating in the zone of maximum auroral occurrence afforded an opportunity for study of auroral effects. The path from Newfoundland to the Azores (1,411 miles) was selected to study problems associated with extreme distance. Other paths were utilized for experiments with such variables as distance dependence and height of the scattering layers.

the pole. The net result is more ionization in the lower region of the ionosphere.

According to one school of thought, ionization by meteors is the dominant mechanism. Literally millions of tiny particles of meteor dust enter the earth's atmosphere every day but usually burn themselves out before striking the surface. Their passage through the atmosphere produces trails of intensely-ionized gas which scatter radio waves. The meteor theory says that there are enough meteors to produce a continuous mechanism for propagation by the overlapping trails of ionization, and that this is the dominant contribution to the received signal. There is experimental evidence that this is true at some times of the day, particularly in the early morning hours.

The principal factors that limit the utilization of ionospheric forward scatter are frequency and distance. The experimental approach has been to isolate the different variables and evaluate them individually. However, it has been difficult to express a relationship with frequency.

The useful frequencies are between 25 and 60 Mc. The signal strength falls off very rapidly as the frequency is increased. Thus the lower frequencies of the range will generally permit more efficient transmission. However, if too low a frequency is chosen, ionospheric reflection will also take place at certain times, and then the scatter circuit may be affected by multipath propaga-

tion of its own transmission or by other transmissions, or it may cause interference in other circuits.

Distance dependence is governed largely by (1) the magnitude of the scattering angle, and (2) the height of the layer of the ionosphere that produces the scatter. The scattering angle is defined as the angle between the incident wave and the scattered wave that reaches the receiver.

As observed in the NBS tests, the strength of the scattered signal falls off very rapidly as the scattering angle is increased. This occurs as the path is shortened. At less than about 600 miles the ionospheric signal becomes too weak for practical use.

At the longer distances, the signal intensity is usable because the angle is small, until the limiting distance is reached. The maximum distance is reached when the portion of the ionosphere from which scattering occurs meets the horizon as "seen" from the transmitter. Increasing antenna height helps slightly toward increasing the distance range.

In 1913, Kennelly suggested the possibility that radio waves might be scattered as well as reflected by the ionosphere. In 1932, Eckersley proposed a theory of scattering to account for certain special effects he observed, but no one appears to have seriously proposed ionospheric scattering as a useful communication mechanism until 1950. In December of that year a group of radio scientists holding a conference at Massachusetts

Institute of Technology suggested that scattering in the ionosphere might produce a signal sufficiently strong to be useful, provided a strong transmitter, high-gain antennas, and a sensitive receiver were used. The group included L. V. Berkner, then of Carnegie Institution of Washington; H. G. Booker, Cornell University; E. M. Purcell, Harvard University; W. W. Salisbury, Collins Radio Co.; J. B. Wiesner, M. I. T.; and D. K. Bailey, R. Bateman, and G. F. Montgomery of the NBS staff.

A cooperative experiment was promptly arranged in which the M. I. T. Lincoln Laboratory sponsored operation of a transmitting site by the Collins Radio Co. at Cedar Rapids, Iowa, while the National Bureau of Standards operated a receiving site at its field station at Sterling, Va. The distance is 773 miles.

After experimental transmissions during the next month had demonstrated that signals were continuously received and that they exhibited interesting and promising behavior during ionospheric disturbances, a program of further experimentation was formulated. Transmissions on 49.8 Mc over the original path have continued without interruption since January 23, 1951. The program has subsequently been enlarged in various ways, but always with the dual objective of (1) investigating the physical principles and theories involved in ionospheric scatter, and (2) providing engineering information for the design, construction, and operation of communication systems. The work at NBS has been carried out by a group headed by Bailey, Bateman, and R. C. Kirby, under the sponsorship of the Department of Defense and the Air Force.

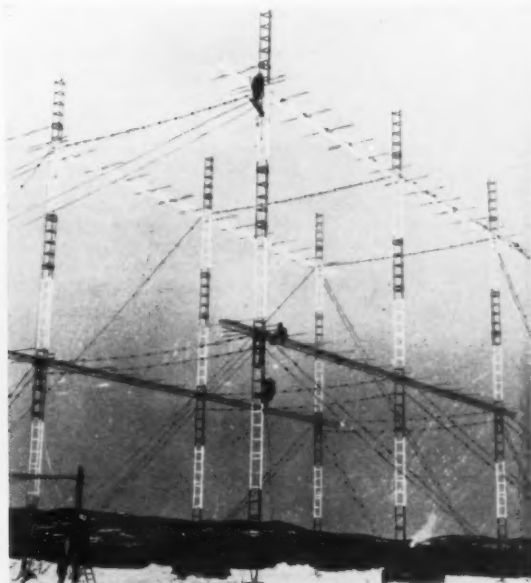
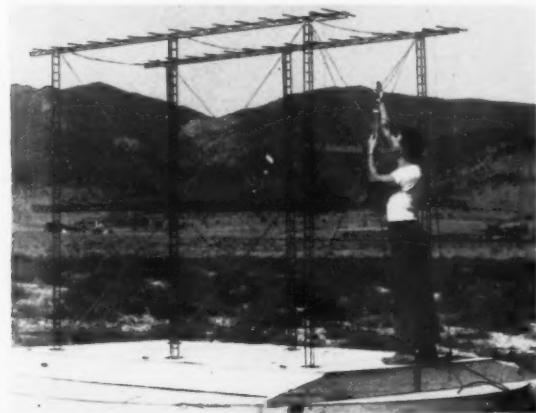
In addition to the Cedar Rapids-Sterling path, which has been operated continuously, several other paths have been studied for shorter periods of time. Since the method offers the advantage of reliability during ionospheric disturbances such as auroral storms and

polar blackouts, three paths were established in regions where the aurora is most active.

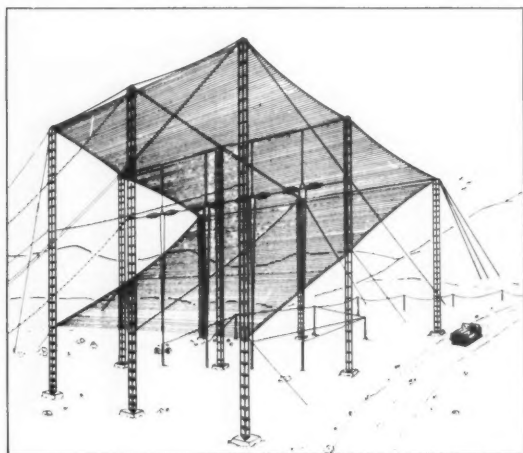
One, from Fargo, North Dakota to Churchill, Canada, terminated practically in the zone of maximum auroral occurrence. The other, from Anchorage to Barrow, crossed the maximum auroral zone practically at the midpoint of the path. An ionospheric station at Fairbanks provided soundings at the approximate midpoint. These paths were almost the same length as the Cedar Rapids-Sterling path so that effects due to differing distances were eliminated. Another auroral-zone path was also tested in 1952 and 1953 from Goose Bay, Labrador, to Sondre Stromfjord, Greenland. Much valuable data on the characteristics of these paths were obtained.² The investigators found that with careful design of the path components, it is possible to communicate with very high reliability even in these regions where communication by ionospheric reflection is often badly disrupted by natural phenomena.

A path from St. John's, Newfoundland to Terceira Island in the Azores gave an opportunity to study problems associated with extreme distance—1,411 miles in this case. Here the terrain was such that high antenna sites could be chosen overlooking the ocean. Under these circumstances it was verified that a distance of 1,400 miles is feasible for reliable operation. An interesting feature of this test is that it combined frequency-standard techniques and propagation measurements in improving the efficiency of the test setup. Portable standard-frequency oscillators developed by P. G. Sulzer of NBS were employed at both the transmitter and receiver to permit using a 40-cycle receiver bandwidth at 36 Mc transmitter frequency. This reduced the necessary transmitter power and antenna gain by improving the signal-to-noise ratio of the circuit.

Precise scale models of antennas have been constructed and studied systematically at the Bureau's model antenna ranges. The model below is of the huge Yagi array shown at right. In locations where space is limited or the ground is not suitable for constructing large rhombic antennas, Yagi arrays are generally used. An installation in the Arctic is shown.



In addition, short-term experiments for studying other variables utilized other paths, mostly from Cedar Rapids and from Sterling. Tests of reception near the maximum distance were carried out from Cedar Rapids to Dade City, Palmdale, and Homestead, all in southern Florida. In 1952 and 1954 short-distance tests were made from Sterling, Va., to Bluffton, S. C. In these tests the time of arrival of ionospheric scatter waves was compared with that for more direct tropospheric signals. This gave direct evidence concerning the height of the scattering layers. In 1951 an attempt was made to look for scattering from higher layers such as the F₂, on a path from Cedar Rapids to Bermuda. This path was chosen as being sufficiently long so that the lower layers would be well beyond the horizon. At the frequency used—near 50 Mc—occasional weak signals were observed, and these were attributable to other mechanisms.



As part of the United States participation in the International Geophysical Year, it is planned that NBS will carry out in 1957-1958 an ionospheric scatter experiment in Peru, where the midpoint of the path will be nearly at the geomagnetic equator. This experiment will determine scattering behavior in a geographical region having ionospheric characteristics not previously studied from the scattering standpoint. The possibility of high-level scattering in that region will be investigated.

Large rhombic antennas have been used at both ends of the path for most of the experiments. Where space and suitable terrain were not available for rhombics, Yagi arrays were usually substituted. In order to obtain a suitable comparison between the different types of antennas, various combinations were installed at several transmitting and receiving sites. In some experiments, transmitter and receiver were switched alternately between two antennas at half-hour intervals. For example, a combination of rhombic to rhombic and Yagi, and of Yagi to rhombic and Yagi, was operated for a time between Anchorage and Barrow. Here the two receiving antennas were used simultaneously and

continuously. For continuity in observations on the Cedar Rapids-Sterling path, the rhombic antennas were always used as the reference pair.

Rhombic antennas up to 25 wavelengths on a side have been constructed. For a frequency of 50 Mc, approximately that used on all paths except Newfoundland-Azores, this means 500 feet on a side. Construction and successful application of antennas of such size confirmed that conventional design of rhombic antennas could be extended to larger sizes, as detailed by Harper.

In order to study antenna patterns and to help in predicting performance, scaled systems were constructed. If the system is scaled small enough, experimental measurements can be made within a reasonable distance of the antenna. Precise scale models of the antennas were thus studied systematically.

In view of the promising characteristics of the new mode of ionospheric propagation in arctic regions, the U. S. Air Force asked the Bureau in 1951 to assume responsibility for setting up the first regular communication circuit using ionospheric scattering in the VHF. Initially a 48 Mc experimental 1-way circuit was tested between Labrador and Greenland. This was followed by a complete prototype system operated at frequencies

Large corner antennas designed and constructed by E. C. Page Consulting Radio Engineers in cooperation with NBS, are being studied for effectiveness in comparison with other types of antennas. Note size in relation to automobile.

between 30 and 40 Mc, consisting of three 2-way circuits extending from Maine to northern Greenland. Recently this system has been extended under NBS supervision from Goose Bay, Labrador, via Narsarsuaq, Greenland, to Reykjavik, Iceland. Detailed engineering design was worked out with the help of the E. C. Page Consulting Radio Engineers and the installation was contracted to that firm.

Since only a small portion of the transmitted signal is scattered by the ionosphere, it is necessary to use large amounts of gain in a communication system. This calls for powerful transmitters, high-gain antennas, and sensitive receivers. The operating circuits that have been installed use 40-kw transmitters, high-gain antennas designed by NBS, and sensitive receivers designed by M. I. T. Lincoln Laboratories.

The complete 4-channel multiplex radio teletype systems began operation in 1953. After a brief trial period, the prototype circuits were made available to the Air Force for test traffic. A careful attempt was made to obtain accurate performance reports and to provide information on the problems and weaknesses of these facilities. In the first year, traffic utilization was achieved 91 percent of the time. Propagation difficulties accounted for circuit outage 1.1 percent of the time.

¹ The VHF range extends from 30 to 300 Mc.

² For technical details, see Radio transmission at VHF by scattering and other processes in the lower ionosphere, by D. K. Bailey, R. Bateman, and R. C. Kirby, *Proc. IRE* 43, 1181 (1955).

Corrosion Resistance of Aluminum Alloys

THE BUREAU has found that some aluminum alloys can resist corrosion in either a marine or inland atmosphere for at least 20 years.¹ These results were obtained in a long-range study conducted by F. M. Reinhart and G. A. Ellinger of the NBS staff for the Navy Bureau of Aeronautics. Besides determining the corrosion resistance of a large number of aluminum alloys, the study also provides data regarding the effects of heat treatment and protective coatings on corrosion rates.

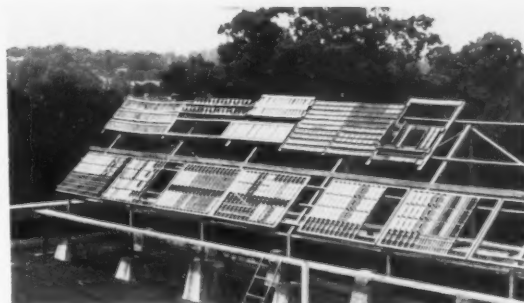
By the early 1930's experimental "high-strength" aluminum alloys had been developed for aircraft use, but little was known of their corrosion properties after sustained exposure. There were also many new protective coverings for aluminum such as organic paints and inorganic coatings. The Bureau therefore undertook to investigate the commercial and experimental alloys then available, together with the coatings used for surface protection, by exposing them to various weathering conditions for a period of 20 years. The NBS study thus provides data on the 20-year corrosion resistance of aluminum alloys which in some cases have only recently been converted from experimental to commercial status.

The alloys studied (table 1) included those which could be hardened by heat treatment and those not susceptible to heat treatment. Among the latter were aluminum-manganese 3004-H34 and aluminum-magnesium 5254-H34.² The alloys amenable to heat treatment included clad and bare aluminum-copper alloys 2017 and 2024. Other alloys contained nickel, cadmium, or copper and cadmium. Aluminum-magnesium-silicon alloys, in which hardening is due to the intermetallic compound MgSi, were also studied.

Specimens 0.75 in. by 9 in. long were exposed in selected locations at Washington, D. C., Norfolk, Va., and the Canal Zone. The latter constituted the tropical marine atmosphere, whereas Washington and Norfolk were the temperate inland and marine locations. All of the marine specimens were exposed near the shoreline, where they were occasionally wet by spray.

Studies were made of the aluminum-copper alloy 2017 with a number of different finishes. Included were samples of clad and bare 2017—several heat-treated by selected methods and some protected with various types of organic or inorganic coatings.

The effects of corrosion on each alloy were evaluated by visual and microscopic examination and by the change in its elongation.³ The samples were removed at intervals from the racks, beginning 3 months after the start of the test, and were subjected to tensile tests. The tensile strength and elongation after exposure were compared with values obtained on control specimens. The control values for elongation were obtained by averaging the original values and the values obtained on specimens stored in desiccated containers for comparable periods of time. Statistical analysis showed no



For exposure to inland atmosphere, aluminum alloy specimens were placed on the roof of this building at the Bureau in Washington, D. C. Marine-atmosphere specimens were placed in similar racks at Norfolk, directly over the water 10 feet above the mean tide level. Both racks inclined specimens at an angle of 45°.

significant differences in these values with respect to time of storage, surface treatment, or paint coating.

The Bureau found that improperly heat-treated aluminum-copper alloys failed by intergranular corrosion and severe exfoliation with no measurable elongation after exposure, while those properly heat-treated performed satisfactorily. However, 2017, when clad with a thin, low-strength alloy, resisted corrosion very well even if incorrectly heat-treated. The alloys 3004-H34, 5050-H34, and 5254-H34 showed excellent resistance to corrosion, as did the cadmium alloy, but alloys containing both magnesium and silicon showed evidence of intergranular attack.

Spot-welded specimens of 3004-H34, clad 2017-T4, and clad 2024-T36 showed no decrease in breaking strength after 1,044 weeks in a marine atmosphere or 1,140 weeks in an urban atmosphere. When tested, these specimens ultimately sheared through the welds,

Equipment below was used for testing tensile strength and elongation of aluminum alloys. Specimen is held in tension by grips (left). An extensometer, fastened to center section of specimen, feeds stretch data to stress-strain recorder (center) while recording pen indicates applied load. After specimen breaks, actual elongation is measured and recorded. Some alloys studied had same elongation values after 20 years' exposure over salt water as they had prior to exposure.



TABLE 1. Chemical composition of aluminum alloys

Designation of materials ^a		Chemical composition, percentage by weight								Remarks
Aluminum Assoc. (or producer)	ASTM	Al ^b	Cu	Mg	Mn	Fe	Si	Cr	Other elements	
5050-H34		97.98	0.02	1.24	0	0.37	0.20	0.19		
5254-H34	GR40A-H34	95.79	.02	3.57	0	.23	.14	.25		
3004-H34	MG11A-H34	97.32	.10	0.89	1.04	.43	.22			
X5056-H34		93.73	.05	6.01	0	.13	.08			
6131-T6		97.61	.05	0.51	.01	.52	1.08	.22		
6051-T6 ^c		97.95	.05	.61	.01	.38	1.00			No chromium.
Clad 2017-T4 ^d	Clad CM41A-T4	93.75	4.10	.59	.58	.48	0.50			
Clad 2024-T3 ^d	Clad CG42A-T3	93.44	4.17	1.59	.57	.14	.09			
Clad 2024-T36 ^d	Clad CG42A-T36	93.44	4.17	1.59	.57	.14	.09			
Nicalium D2018		96.52	0.45	0.48	.19	.42	.30	.20	Ni, 1.01; Mo, 0.17; Zn, 0.18; W, 0.08.	Furnished by Nicalium Co.
Inalium ^e		96.50		.80		.25	.45		Cd, 2.0	French alloy.
Aeral ^e		92.55	3.75	.80	.25	.25	.40		Cd, 2.0	Do.
2017-T4	CM41A-T4	94.02	3.94	.56	.57	.47	.44			
2017-T6	CM41A	94.17	3.76	.55	.53	.48	.51			
2017-T36	CM41A-T36	94.45	4.17	.53	.58	.16	.11			
2024-T36	CG42A-T36	93.44	4.17	1.59	.57	.14	.09			
2025-T3		93.67	4.20		.68	.45	.90			

^aAnalyses by the cooperating manufacturer, the Aluminum Co. of America, unless otherwise indicated.

^bBy difference.

^cAnalysis by the National Bureau of Standards.

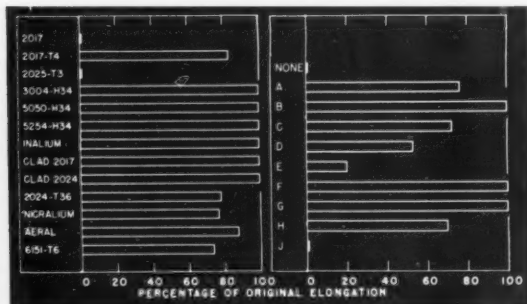
^dAnalysis of the core material. Cladding 99.75 percent aluminum (1075).

^eNominal composition furnished by the manufacturer, Le Société des Brevets Berthelmy de Montby, Paris, France.

^fMaterial subsequently heat treated at the National Bureau of Standards in various ways.

or the nuggets pulled out of one of the pieces of metal. Likewise, there was no decrease in the breaking strength of clad 2017-T31 joined with 2017-T31 alloy rivets or of aluminum-magnesium 5254-H34 joined with 3004-H32 rivets after the same periods of time. However, rivets made of X5056-H32, an alloy having about twice

Below: Chart at left shows percentage of original elongation after 20 years exposure for aluminum alloys studied by NBS. Aluminum-copper alloys 2017 and 2025-T3 failed by intergranular corrosion and exfoliation due to improper heat treatment. Mechanical properties of nonheat-treatable alloys 3004, 5050, and 5254, and of the clad aluminum-copper alloys, were not affected. Chart at right shows percentage of original elongation after 20 years for aluminum-copper alloy 2017 protected by various paints applied over Bengough anodic treatment. Compositions were: A, Long oil ester gum varnish and aluminum powder; B, vinyl resin with aluminum powder; C, phenol formaldehyde and aluminum powder; D, varnish (33 gal.) with zinc chromate and iron oxide; E, phenol formaldehyde, zinc dust, and zinc oxide; F, phenol formaldehyde, zinc chromate, and zinc oxide; G, one coat of F plus two of A; H, three coats of glycerol phthalate with aluminum powder; J, unpigmented glycerol phthalate. Paints F and G also gave complete protection to unclad, uncoated alloys for a period of 20 years.



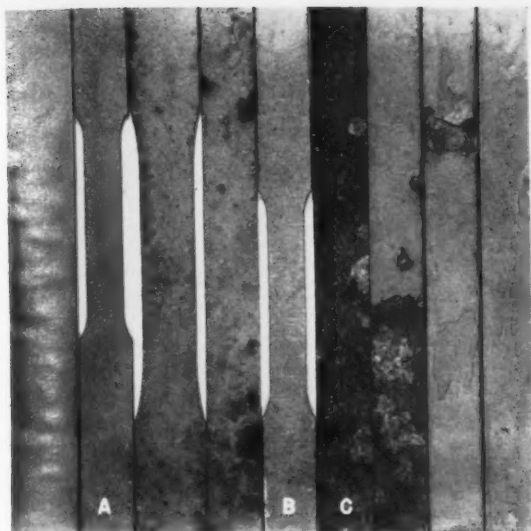
as much magnesium as 5254, were attacked intergranularly, and the heads fell off during the exposure tests.

The Bureau studied a number of protective coatings for aluminum alloys, including oxide coatings formed anodically or by simple immersion in solutions of chemicals, as well as organic coatings of various formulations. These coatings were applied singly and in combination. The Bureau's tests showed that the Bengough (chromic acid) anodic treatment did not increase the corrosion resistance of the untreated 2017 alloy in either the ice water-quenched and artificially aged or hot water-quenched conditions. Nor was corrosion resistance improved on similar specimens by the sulfuric-acid anodic process, where the specimen is sealed by immersion in boiling water for 30 minutes.

One of the protective coatings studied was a paint consisting of a long-oil ester gum varnish combined with aluminum powder. When applied over the various oxide coatings, this paint increased protection considerably in most cases. The Bureau also studied other paint systems applied to the bare alloy 2017. It was

Riveted specimens of aluminum alloys after 7 years' exposure at Norfolk. Pair at left is of aluminum-copper alloy clad 2017 with rivets of 2017-T31 alloy. Pair at right is of aluminum-magnesium alloy 5050 fastened with 3004, aluminum-manganese, rivets. Rivets in center pair were of X5056 alloy; these were attacked intergranularly and fell apart before removal from exposure.





Specimens at left are aluminum-copper alloy 2017 after 7 years' exposure over sea water at Norfolk. Specimens were hot-water-quenched, except for A, which was correctly heat-treated. B, although hot-water-quenched, was fairly well protected by a long oil ester gum varnish pigmented with aluminum powder. Specimen C, which was severely corroded during exposure, was covered by a clear varnish only.

found that two coats of varnish and aluminum powder applied over a zinc chromate pigmented primer gave complete protection to the bare alloy for over 20 years. The elongation of the 2017 clad alloy, even when not painted, was not changed by exposure for 20 years.

Since the Bureau's investigation was begun, the compositions of some of the alloys studied have been al-

tered to improve resistance, and the use of other alloys has been discontinued altogether. The noncopper alloys, such as 3004 and 5254, are highly resistant to corrosion and are in wide use where lightness, durability, and corrosion resistance are required. The aluminum-copper alloy, 2017, has been replaced by clad 2024 for aircraft structural members but is still used for the extruded forms incorporated in airplane assemblies.

¹ For further technical details see Effect of 20 year marine atmosphere exposure on some aluminum alloys, F. M. Reinhart and G. A. Ellinger, ASTM STP 175 Atmospheric corrosion of non-ferrous metals (in press).

² The present Aluminum Association designations are given where applicable, otherwise the manufacturer's designation is given. The first four digits refer to the composition of the alloy. A letter plus one or more digits refers to the temper designations, as follows: H34—strain hardened and stabilized; T3, T31, T34, and T36—solution heat-treated and cold worked; T4—solution heat-treated; T6—solution heat-treated and artificially aged.

³ Elongation of a tensile specimen is defined as the total deformation (stretch) in the direction of load, or per unit of length, caused by a tensile force.

Two New Radiation Handbooks

THE increasing use of high-energy X-rays and radioactive sources in medical diagnosis and treatment and in industry presents problems in all phases of radiation protection and shielding. The National Committee on Radiation Protection, sponsored by NBS, makes recommendations that are published by the Bureau as handbooks two of which have just become available.

X-ray Protection, NBS Handbook 60, recommends standards of safety intended primarily for protecting the radiation worker and the public, although the Handbook acknowledges that the medical profession should exercise great caution and restraint in the use of agents that produce ionizing radiations. Handbook 60 supersedes NBS Handbook 41, *Medical X-ray Protection up to Two Million Volts*, which was published in 1949. Because of the number of copies of Handbook 41 in circulation, the sections in the new publication bear the same numbers as the preceding volume, wherever possible. Handbook 60 gives general rules for working conditions, survey and inspection of installations, planning an X-ray installation, structural de-

tails of protective barriers, maximum permissible weekly radiation dose, and changes in X-ray equipment design. Additional rules are also given for certain specific applications such as therapeutic equipment operated at potentials above 400 kilovolts. Handbook 60, containing 41 pages, with 14 tables and 9 figures, is available for 20 cents from the Superintendent of Documents, U. S. Government Printing Office.

Regulation of Radiation Exposure by Legislative Means, NBS Handbook 61, was prompted by repeated inquiries by State or municipal authorities on the problem of controlling radiation. This topic is very new to all but two or three States. At this time, only two States have comprehensive regulations designed to control all forms of ionizing radiation, and a few other States are developing such regulations. The material in this report will provide a convenient and suitable basis for the development of uniform radiation-control regulations that can be used by States where the need for regulation may be felt. Handbook 61, containing 60 pages and 5 tables, is available for 25 cents from the Superintendent of Documents, U. S. Government Printing Office.

Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, volume 55, No. 6, December 1955 (RP2633 to RP2640 incl.). Annual subscription \$4.00.

Technical News Bulletin, volume 39, No. 12, December 1955.

10 cents. Annual subscription \$1.00.

Basic Radio Propagation Predictions for March 1956. Three months in advance. CRPL 136. Issued December 1955. 10 cents. Annual subscription \$1.00.

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SINCLAIR WEEKS, *Secretary*
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, *Director*

January 1956 Issued Monthly Vol. 40, No. 1

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NBS Publications (continued)

Research Papers

Journal of Research, volume 55, number 6, December 1955. Single copies of the *Journal* vary in price. Single copies of *Research Papers* appearing in the *Journal* are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies of a *Research Paper*. Request for the purchase price should be mailed promptly to that office.

RP2633. First spectrum of barium, Ba I. Henry Norris Russell and Charlotte E. Moore.

RP2634. Compressibilities of long-chain normal hydrocarbons. C. E. Weir and J. D. Hoffman.

RP2635. Absolute calibration of the National Bureau of Standards photoneutron standard: II. Absorption in manganese sulfate. James De Juren and Jack Chin.

RP2636. A new Bunsen-type calorimeter. Ralph S. Jessup.

RP2637. Mass spectra of thermal degradation products of polymers. Paul Bradt and Fred L. Mohler.

RP2638. Heats of combustion of liquid *n*-hexadecane, 1-hexadecene, *n*-decylbenzene, *n*-decylcyclohexane, *n*-decylcyclopentane, and the variation of heat of combustion with chain length. Frances Maron Fraser and Edward J. Prosen.

RP2639. Computation of atomic energy levels: Spectrum of singly-ionized tantalum. R. E. Trees, W. F. Cahill, and P. Rabinowitz.

RP2640. Reflection and transmission of gamma radiation by barriers: Monte Carlo calculation by a collision-density method. Martin J. Berger.

Applied Mathematics Series

AMS45. Table of hyperbolic sines and cosines. 55 cents.

AMS46. Table of the descending exponential. 50 cents.

Circulars

C539. Standard X-ray diffraction powder patterns. Howard E. Swanson, Nancy T. Gilfrich, and George M. Ugrinic. 45 cents.

C553. The ISCC-NBS method of designating colors and a dictionary of color names. Kenneth L. Kelly and Deane B. Judd. \$2.00.

Handbooks

H60. X-ray protection. 20 cents.

H61. Regulation of radiation exposure by legislative means. 25 cents.

Publications in Other Journals

The development of some infrared transmitting glasses. G. W. Cleek and E. H. Hamilton. *Proc. Conference on Infrared Optical Materials, Filters and Films*, held at the Engr. Research and Development Laboratories, Fort Belvoir, Va. (Feb. 1955).

Manganese thermal neutron activation cross section. J. De Juren and J. Chin. *Phys. Rev.* (57 E. 55th St., New York 22, N. Y.) **99**, No. 1, 191 (July 1955).

The spectral radiant energy from the sun through varying degrees of smog at Los Angeles. Ralph Stair. *Proc. Third National Air Pollution Symposium* (612 S. Flower St., Suite 332, Los Angeles 14, Calif.) **48**, (April 1955).

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